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Performance of Precast Concrete Stay-in-Place Forming System for Lock Walls Rehabilitation

by James E. McDonald and Robert R. Bottin, Jr.

PURPOSE: The Hydraulic Engineering Technical Note (HETN) herein provides an assessment of the performance of precast concrete lock wall panels at Allegheny River, Lock and Dam No. 4. Design and construction methods used in the rehabilitation are applicable to other lock projects within the U.S. Army Corps of Engineers' areas of operation.

INTRODUCTION: Allegheny River, Lock and Dam No. 4 is located about 44 km (24 miles) upstream of Pittsburgh, PA, where the Allegheny River joins the Monongahela River at the headwaters of the Ohio River. The lock is located within the corporate limits of the city of Natrona, Allegheny County, PA. The lock consists of a single 17- by 100-m- (56- by 360-ft) lock chamber. The land and river walls are standard monolithic concrete gravity structures founded on bedrock. The elevation (el)[1] of the top of the lock walls is 757. The lock chamber has a 3.2-m (10.6-ft) lift with the upper pool el 745.4 and the lower pool el 734.8. The chamber floor is unpaved and irregular, which conforms to the profile of the existing bedrock. The mean chamber floor el is about 723.5. A cross section of the lock is shown in Figure 1.

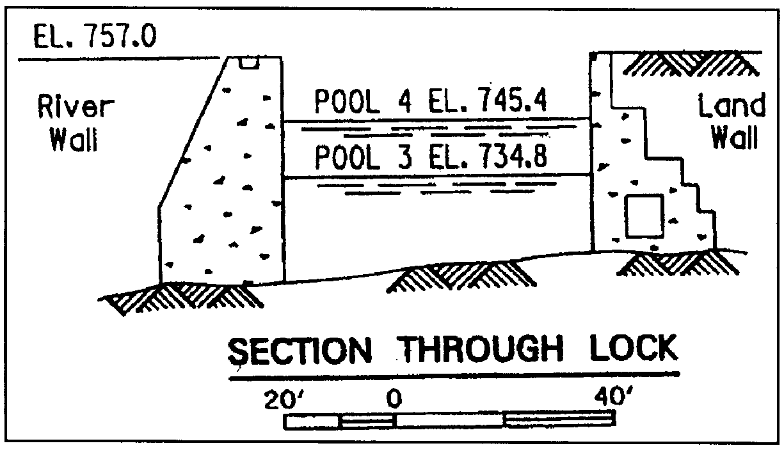

Figure 1. Cross section of Allegheny Lock

BACKGROUND: The Allegheny River lock was constructed between the early to mid 1920s and has been in operation since 1927. Typical of this time period, the concrete was non-air entrained making it more susceptible to damage caused by cycles of freezing and thawing. A major repair of the lock walls was completed in 1966 by conventional cast-in-place concrete and shotcrete repair methods. These repairs did not exhibit the desired durability. Consequently, precast concrete panels were used as a stay-in-place forming system when the lock chamber was

[1] All elevations (el) cited herein are in feet referenced to the National Geodetic Vertical Datum (NGVD). To convert feet to meters, multiply number of feet by 0.3048.

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again rehabilitated in 1994. One foot of concrete was removed from the existing lock walls, and the precast panels were installed. The interior face of the panels had a raked finish to enhance bonding with the infill concrete. The use of precast concrete panels for the lock walls proved to be a timesaving and cost-effective method for the rehabilitation. During the rehabilitation, the first monoliths within the chamber, both upstream and downstream, were resurfaced with cast-in-place concrete repair methods since they contained ladder recess and line hook assemblies.

PRECAST CONCRETE PANELS: Concrete panels used in the rehabilitation were steel-reinforced. A minimum compressive strength of 4,570,150 kgs/sq meter (6,500 psi) and a maximum water-cement ratio of 0.40 was specified in their design. Typical panels were 16.5-cm- (6-½ in.-) thick and 5.5-m- (18-ft-) long. Three rows of precast panels were installed on each wall with 2.1- and 2.4-m- (7- and 8-ft-) high panels on the land and river walls, respectively. A total of 48 panels were required for the land wall, and 45 panels were needed for the river wall. A 0.3-m (1-ft) taper was detailed at the ends of most panels to create a 2.5-cm (1-in.) recess at vertical joints between panels. In addition, a vertical control joint 5.1-cm- (2-in.-) wide and 3.8-cm- (1.5-in.-) deep was included at the center of each panel. A 25- by 15-cm (1- by 6-in.) recess also was detailed at the top and bottom of each panel to allow for installation of form anchor bars. Panel design, fabrication, and installation details may be obtained from Rozzi (1995 and 1996). A view of the lock wall panels is shown in Figure 2.

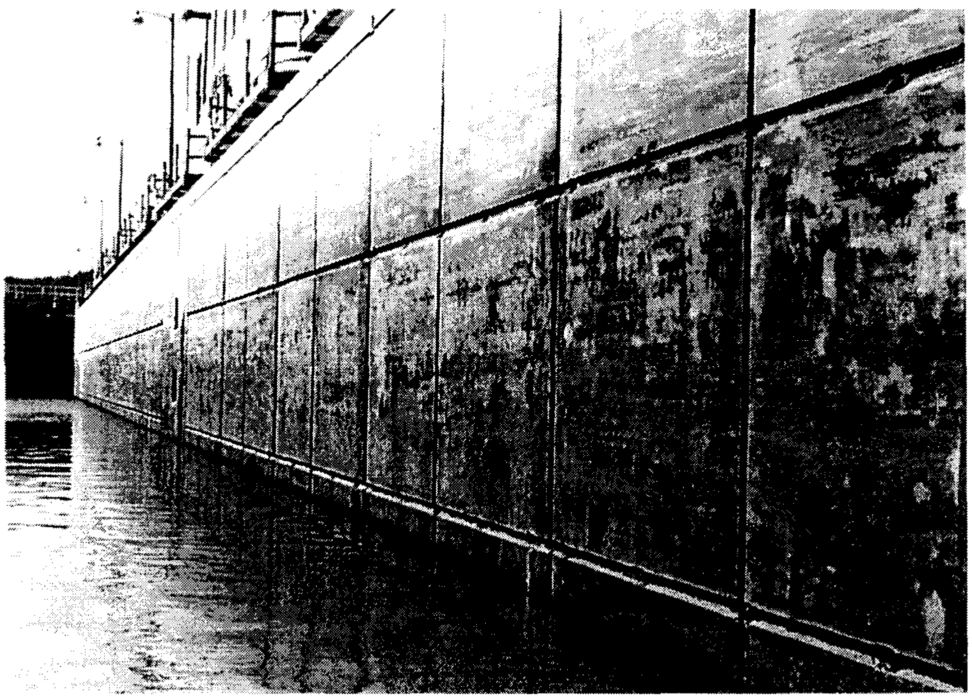

Figure 2. Precast lock wall panels

PRECAST CONCRETE LOCK WALL PERFORMANCE: Since this was the first project of its kind for both the Pittsburgh District and the Great Lakes and Ohio River Division, and considering the age of other locks in the Corps, the Great Lakes and Ohio River Division nominated the project for monitoring under the Monitoring Completed Navigation Projects (MCNP) program (USACE 1997). An initial monitoring effort was conducted as part of the

Periodic Inspections work unit of the MCNP program to evaluate the performance of the lock walls. The inspection of the completed rehabilitation occurred during September 1998. The precast panels were visually inspected from a boat. The top row of panels and the horizontal joint between the top two rows of panels on each wall were inspected with the water in the chamber at upper pool level. The water was then lowered to lower pool level for inspection of the remainder of the middle row and the upper portion of the bottom row of panels. At the time of the inspection, the precast concrete had been installed for almost four years and exposed to about 6,100 and 7,500 recreational and commercial lockages, respectively. Observations were made relative to cracking, deterioration, vertical joints, horizontal joints, and joint leakage. They are summarized in the following subparagraphs.

Cracking: Cracking in one precast panel out of the total of 93 was observed prior to panel installation. Two hairline cracks starting at the top upstream half of the panel and traversing the face to the center portion of the panel were reported. Similar cracks were observed in the top panel at the upstream end of the river wall following placement of the infill concrete. These cracks were attributed to inadequate shimming during panel installation. Cracks previously reported appeared to be partially healed with a maximum crack width of 0.02 cm (0.008 in.). With the exception of hairline cracks at a few control joints, no additional cracks in the precast concrete were found during the inspection. It was noted that at least one crack was observed in each monolith resurfaced with cast-in-place concrete. Typical crack widths were larger than those in the precast concrete, ranging from 0.02 to 0.04 cm (0.007 to 0.016 in.).

Deterioration: The precast concrete appeared to be in very good condition relative to deterioration, although some localized spalling along joints was observed. Several precast panels in the upper row on the river wall exhibited what appeared to be superficial surface crazing, although there was some question whether the crazing was in the concrete or some deposit on the concrete surface. Cast-in-place concrete surfaces, on the other hand, exhibited extensive bugholes.

Vertical Joints: Tapering the ends of the precast panels to create a recessed joint between adjacent panels appeared to eliminate barge impact on the edges of the panels. Only one panel on the land wall had localized cracking and incipient spalling that was obviously the result of barge impacts within the tapered area. Hairline cracks were observed in a few control joints that would indicate they are effective in controlling cracking. Joints between the precast panels and cast-in-place concrete were not tapered, and thus, exhibited more spalling because of barge impact.

Horizontal Joints: Both walls exhibited localized concrete spalling along the horizontal joints between panels. Joint spalls on the land wall were concentrated along the bottoms of the panels in the upper two rows. Similar conditions were observed on the river wall, except the spalls appeared to be concentrated along the tops of the panels. These conditions may be attributed in part to traffic patterns at the lock. Downbound and upbound traffic reportedly rubs against the land and river walls, respectively. Emptying and filling of the lock chamber under these conditions would tend to cause tensile stresses along the bottom and top edges of panels on the land and river walls, respectively.

Joint Leakage: Minimal joint leakage was observed during the inspection. Observations revealed only minor leakage concentrated along the horizontal joint between the middle and bottom rows of panels in each wall.

CONCLUSIONS AND RECOMMENDATIONS: Overall, the precast concrete lock wall panels appeared to be in very good condition, although there was some localized spalling along the joints. The condition of the lock walls should be monitored periodically in the future to establish the long-term durability of precast concrete as a stay-in-place forming system for lock wall rehabilitation. Discontinuities in lock walls created by joints are usually the areas that are most vulnerable to impact by barges. This attribute was noted for the cast-in-place joints as well. A study to develop an optimum configuration for horizontal and vertical joints that would minimize barge impact in these areas may be warranted as well as an investigation of potential applications of materials with improved impact resistance, such as fiber-reinforced composites.

ADDITIONAL INFORMATION: For additional information contact Mr. James E. McDonald, Concrete and Materials Division, Structures Laboratory, U.S. Army Engineer Research and Development Center (ERDC) at 601-634-3230 or e-mail *mcdonaldj@wes.army.mil*; or Mr. Robert R. Bottin, Jr., Navigation and Harbors Division, Coastal and Hydraulics Laboratory, ERDC, at 601-634-3827 or e-mail *r.bottin@cerc.wes.army.mil.*

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